

Satellite Remote Sensing of Urbanization – The NightSat Concept

Christopher D. Elvidge, NOAA National Geophysical Data Center (chris.elvidge@noaa.gov).

Christopher Small, Lamont-Doherty Earth Observatory (small@LDEO.Columbia.edu).

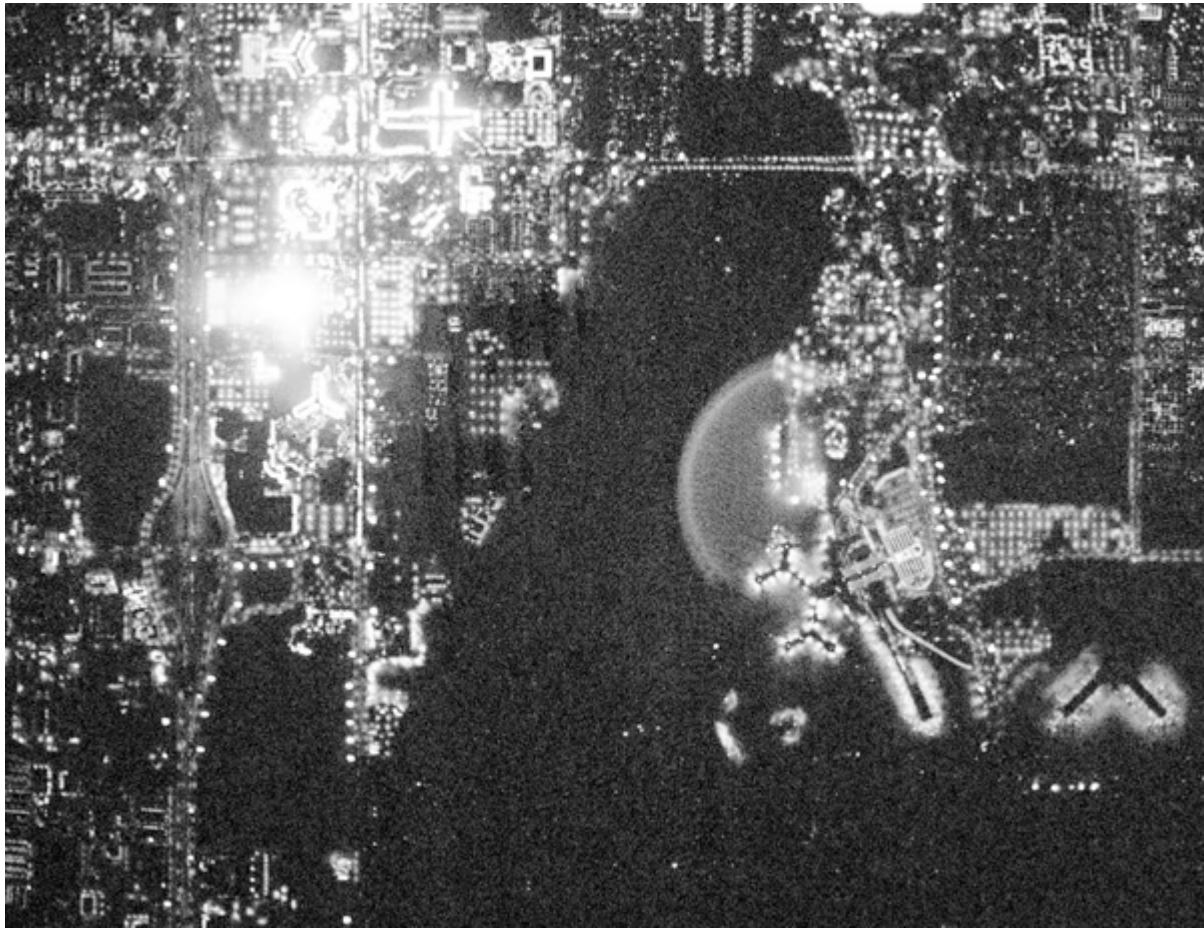
Ramakrishna Nemani, NASA Ames Research Center (ramakrishna.r.nemani@nasa.gov)

John Arvesen, Cirrus Digital Systems (arvesen@cirrus-designs.com)

Introduction: While human settlements occupy only a small fraction of the earth's surface, they are at the center of most of the anthropogenic activities altering the earth environment. Urban areas are the focal points for the consumption of food, water, and energy. They are the primary sources of manmade air and water pollution, plus the carbon emissions associated with fossil fuel consumption. Most of the agricultural, fisheries, and resource exploitation activities which constitute the balance of human impacts on the environment are driven by the consumption occurring in urban areas. The widespread use of impervious construction materials results in vastly increased surface runoff, which alters the stream flow and biodiversity. While percentage of the earth's surface covered by development is small, its influence is enormous. All previous orbiting earth observation systems have been designed with the primary objective of observing natural systems (e.g. clouds, ocean, vegetation) and have not been optimized for direct observation of human activity. We believe that an earth observing sensor designed to provide high spatial resolution global measurements of a pervasive human activity could make a significant contribution to NASA's Earth Science objectives.

Satellite Remote Sensing of Human Activity: Nocturnal lighting is one of the hallmarks of modern human activity. Remote sensing of nocturnal lighting provides an accurate, economical and straightforward way to map the global distribution of urban areas and infrastructure. The Defense Mapping Satellite Program (DMSP) Operational Linescan System (OLS) has provided the most accurate and self consistent mapping of urban (and suburban) extent currently available and these data have been used modeling the population density, impervious surface area, and development impacts on terrestrial carbon dynamics. However, the spatial resolution of the OLS sensor (2.7 km) is not sufficient to resolve important structural components of human settlements. The collection of low light imaging data from space will improve (better spatial resolution and on-board calibration) with the data collected by the NPOESS era by the Visible Infrared Imaging Radiometer Suite (VIIRS). However, the VIIRS data will still be at relatively coarse spatial resolution (0.8 km) and will not extend the detection limits for lights beyond those now accomplished by the OLS.

Digital Camera Sheds Light on Urban Remote Sensing: On September 27, 2004, a NASA Cirrus DCS digital camera (manufactured by Kodak) was used to acquire nighttime visible imagery of Las Vegas and Laughlin, Nevada and the central section of Los Angeles, California from an altitude of 45,000 feet from the NASA ER-2. The camera was able to collect a series of images in which lighting features are observed at 1.6 meter resolution. The image below is a mosaic of frames, covering the Las Vegas strip, the airport, residential areas, and areas devoid of development. Field inspection has revealed that the lights from individual streetlights were detected and that clusters of lights in residential areas produced enough light to be distinguished from background areas having no lights.



Prospects: The successful demonstration of high spatial resolution detection of nighttime lights using an “off-the-shelf” digital camera indicates that it would be possible to collect low light imaging data from a Landsat class sensor. Low light imagery collected at or near the spatial resolution Landsat would reveal a wealth of information on urban morphology and infrastructure that cannot be easily be derived from conventional sensors. Since this system would be optimized for detecting and measuring nocturnal lighting – we refer to it as NightSat. The NightSat objective would be to produce an annual global cloud-free composite of nighttime lights. Using the Cirrus DCS camera (15 degree field of view, and a 4072 by 4072 array) as the starting point for defining a potential NightSat system, it would be possible to collect 45 meter resolution imagery in 185 km swaths from a 705 km high orbit with a 99 minute orbit. If approximately fifty such frames were collected each orbit (focus on land areas) and fourteen orbits per day – the daily data volume would be near ten GB. Simulation of 45 meter low light imaging data from the 1.6 meter collection over Las Vegas indicates that most of the lighting feature content is preserved. It would be best to fly the system in constellation with the VIIRS or similar instrument having nighttime cloud and fire detection capabilities.

Relevance to NASA Earth-Sun System Science: How are global ecosystems changing? What changes are occurring in global land cover and land use, and what are their causes? How is the earth's surface being transformed and how can such information be used to predict future changes? What are the consequences of land cover and land use change for the sustainability of ecosystems and economic productivity? What are the consequences of climate and sea level changes and increased human activities on coastal regions?